Towards a Solid State Terahertz Oscillator:
Bloch Oscillation in an Electrical Biased Superlattice

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A solid state terahertz oscillator is essential to fill the terahertz technology gap that exists between high frequency electronics and long wavelength photonics. Current research and development at UCSB attempts to use the terahertz gain provided by a Stark ladder in a semiconductor superlattice, in a uniform electric field. It is expected that at frequencies below the Stark splitting, the system will provide gain, while frequencies above the Stark ladder splitting the system will be lossy. No population inversion is required.

To provide sufficient gain to overcome loss, and deliver useful power, high current density superlattices are required. High current density requires relatively broad minibands and under these conditions the Stark resonance or splitting is equivalent to Bloch oscillation. To realize the anticipated gain just below the Bloch frequency, the superlattice needs to experience a uniform electric field. But, the system is unstable to the formation of electric field domains. To stabilize a uniform electric field we have proposed to shunt superlattices with bulk material with sufficient conductance to constrain the DC electric field without introducing significant terahertz loss. It appears that InAs/AlSb superlattices shunted by high mobility InAs material may be the material of choice.

Using an insitu-etching chamber connected to an MBE system we have regrown InAs in contact with the InAs/AlSb mesas. The regrown material has an electron density of $10^{17}/cm^3$, a mobility at room temperature of ~ 12,000 $cm^2/volt \cdot sec$ and contact resistance to the superlattice mesa of the order of $<10^{-5}\ \Omega \cdot cm^2$. While the regrowth of a shunt to stabilize the electric fields appears promising, the regrown InAs emerge with densities that are nearly an order of magnitude too large. Further the superlattice I-V's exhibited a reversible breakdown and current upswing, reversible “breakdown”, at relatively low voltages.

To improve the current saturation characteristics, we have begun to explore InGaAs/AlAs superlattices. This material exhibits the desired electron densities, currents that saturated at the appropriate voltages and no reversible "breakdown".

Current effort focuses on fabrication of quasi-optical arrays of InGaAs/AlAs and InAs/AlSb , growth of shunting layers by reorganization of the mesa edge and test of the terahertz response in cavity configurations with the UCSB free-electron lasers.

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